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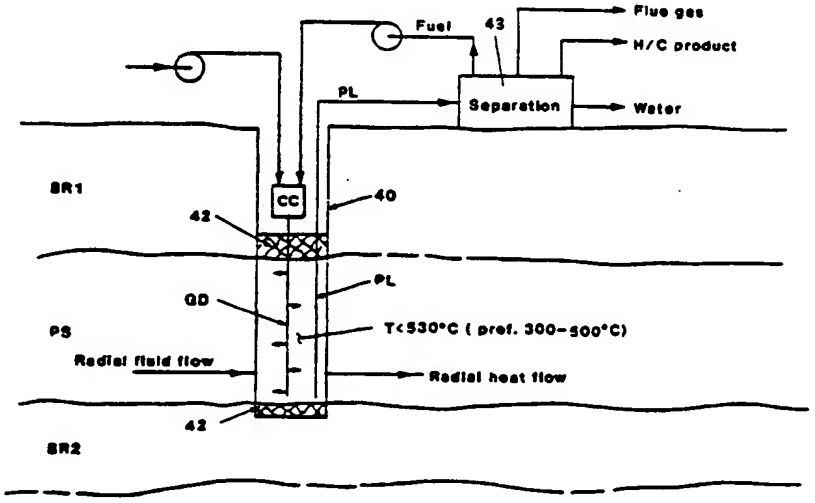

(57) Abstract

An enhanced hydrocarbon recovery technique for recovering hydrocarbons from host rock, in which the host rock is heated to induce thermal pressurisation of hydrocarbons contained therein. The induced pressurisation increases the mobility of the hydrocarbons sufficiently to allow them to be released from the host rock. In some rock formations the induced thermal pressurisation may also cause fractures to be formed within the host rock. Such induced microfractures form a network of connections between pores within the host rock thus increasing permeability and allowing the release of the vapourized hydrocarbons. The process has particular application to the recovery of tight oil from rock formations characterised by low permeability. The process may also be employed in combination with other secondary recovery techniques such as in-situ combustion and artificially fracturing the host rock by means of hydraulic fracturing or by detonating an explosive charge within the host rock.

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ENHANCED HYDROCARBON RECOVERY METHOD

FIELD OF THE INVENTION

The present invention relates to an enhanced hydrocarbon recovery method and relates particularly, though not exclusively, to tight oil recovery by induced thermal pressurisation (TORBIT).

BACKGROUND TO THE INVENTION

Throughout the following description reference will be made to the recovery of tight oil, however it is to be understood that the invention is not limited in its application to tight oil. The enhanced hydrocarbon recovery technique of the invention may also be applicable to other rock formations characterised by low permeability and/or low porosity which do not contain tight oil, or to host rock that is not sufficiently susceptible to conventional recovery techniques alone. The technique may also be applicable as a replacement for conventional secondary and/or tertiary hydrocarbon recovery techniques.

Tight oil is so called because it is tightly locked away in a rock formation of low permeability and cannot be efficiently recovered using conventional recovery techniques. It is sometimes also referred to as "old oil" because it may be found in very old rock formations, typically Precambrian rock. Significant reserves of tight oil are known to exist in North America, North Africa and Australia. In the Northern Territory of Australia the McArthur Basin is thought to be Middle Proterozoic in age (1400 - 1800 Million years old). The McArthur Basin contains significant tight oil reserves in the Velkerri Formation which comprises shales and siltstones having high organic carbon content. The Velkerri siltstones have been identified as host rock for tight oil, and are characterised by low porosity (2 - 10 %) and very low permeability (0.01 - 0.5 milliDarcys (mD)). It is estimated that the Velkerri siltstones alone contain 700 Mbbls of oil.

The low permeability of the host rock precludes oil

flow, and the small pore spaces and low occurrence of natural fractures also make it difficult to stimulate hydrocarbon flow. These factors render conventional stimulation techniques less viable for the recovery of tight oil. Conventional recovery techniques include the following:

Steam Stimulation/Steam Flooding

This method is useful in reservoirs having high permeability (above 1000 mD) and high porosity (above 20%), containing highly viscous oils. The method involves injecting steam into a reservoir to increase its temperature, thus lowering the viscosity of heavy oils and increasing reservoir pressure.

Electromagnetic Heating

This method involves heating the reservoir electromagnetically by a device lowered down the well, having an electric current passed through it. The well casing acts as a waveguide, supplying power to an electrode embedded in the deposit. This method is suitable for reservoirs at low pressure (shallow) and good permeability, containing highly viscous heavy oils. The electromagnetic heating typically raises the temperature to the 100°C region, to reduce viscosity and increase the pressure of the oil to stimulate flow.

In-situ Combustion

This is a thermal recovery technique in which the hydro-carbon bearing reservoir is heated by in-situ combustion to reduce the viscosity and improve the mobility of the oil. Ignition is initiated in one well bore and an oxygen-containing gas, such as air, is injected into the well bore to support combustion and to drive a combustion front through the reservoir to a production well. The technique works well in formations with high porosity and high permeability.

Hydraulic Fracturing

This method employs water based fluids containing proppants to fracture the reservoir rock and prop open the fractures. The fractures create artificial permeability and facilitate higher flow rates into production wells. Reservoirs best suited to hydraulic fracturing are typically characterised by low permeability, with high pore pressures and few swelling

clays.

Sometimes two or more of the above secondary recovery techniques are combined. For example, US 3,981,362 describes a method utilising a fracturing technique together with in-situ combustion. The reservoir is first fractured with a combustive fracturing mixture, then the mixture is burned in the fractures, and thereafter finely divided or fluidised carbon in an inert gas carrier is injected into the formation, together with an oxygen-containing gas so as to burn the carbon in the fractures and to establish a hot inert gas drive through the reservoir.

Conventional recovery techniques are not cost effective for tight oil production due to the low permeability and low porosity of the host rock. Furthermore, even in rock formations where conventional recovery techniques may be applied a significant proportion of the oil reserves may not be recoverable. The present invention was developed with a view to providing a more cost effective enhanced oil recovery method for the production of oil from host rock that is not sufficiently susceptible to conventional recovery techniques alone.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a method of recovering hydrocarbons from host rock, the method comprising:

heating the host rock to induce pressurisation of hydrocarbons contained therein whereby the mobility of the hydrocarbons is increased sufficiently to allow the hydrocarbons to be released from the host rock.

Typically the host rock is heated to a temperature at which vaporisation of hydrocarbons and/or water occurs. Preferably the host rock is heated to a temperature within the range 150 - 530°C, more preferably 200 -500°C. In a preferred form of the invention the method comprises heating the host rock in-situ, for example, by means of an electrical heater lowered into a borehole traversing the host rock or by injecting hot inert gas into the borehole. In this context,

inert gas is taken to mean any gaseous stream that contains substantially no free oxidant or that will not support combustion. Such inert gas may, for example, be generated by partial combustion of hydrocarbons or by indirect heating of gases such as nitrogen. Alternatively, the host rock can first be mined and then subjected to heating by external heating means.

In some applications, the method of the invention may advantageously be combined with other secondary recovery techniques. For example, the method of the invention may be combined with a technique for artificially fracturing the host rock, and/or a method of in-situ combustion or pyrolysis.

According to another aspect of the present invention there is provided an apparatus for recovering hydrocarbons from host rock, the apparatus comprising:

means for heating the host rock to induce pressurisation of hydrocarbons contained therein whereby the mobility of the hydrocarbons is increased sufficiently to allow the hydrocarbons to be released from the host rock.

In one form of the invention said means for heating comprises means for injecting heated inert gas into a borehole traversing the host rock.

Typically the apparatus further comprises means for collecting the hydrocarbons released from the host rock.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to facilitate a more thorough understanding of the nature of the invention several embodiments of methods and apparatus for recovering hydrocarbons according to the invention will now be described in detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 illustrates an electrical heater in-situ, that may be employed in one embodiment of the method of the invention;

Figure 2 illustrates an alternative method for implementing the invention;

Figure 3 illustrates another method for implementing the invention;

Figure 4 illustrates a further method for implementing the invention; and,

Figure 5 illustrates a still further method for implementing the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Essentially, the method of the invention involves heating the host rock to a temperature at which pressurisation of hydrocarbons contained therein is induced to increase the mobility of hydrocarbons present in the host rock. Typically the process involves controlled heating of the host rock and the hydrocarbons and water contained therein to the temperature at which vaporization of the hydrocarbons and/or water occurs. The temperature will vary depending on the nature of the hydrocarbon compounds in the host rock, however typically vaporisation of most of the hydrocarbons occurs between 200 - 530°C. Vaporization may have the effect of significantly increasing the mobility of the hydrocarbons since the gaseous phase can move through the host rock at much higher velocities than the liquid phase, which may be substantially immobile. Furthermore, at these temperatures, the vapours also exert pressure on the walls of the pores in the host rock and if the induced pressure is sufficiently high will fracture the rock, forming connections between adjacent pores. The development of high induced pressure will be favoured in formations with low porosity and low permeability. Such induced microfractures will form a network of connections between pores thus increasing host rock permeability and allowing the liberation of the vaporised oil. This is particularly advantageous in host rock containing tight oil where an increase in the permeability of the host rock is required to liberate the oil. The vaporised hydrocarbons are then collected and condensed to recover the oil. Hydrocarbons recoverable by this technique may include hydrocarbon gases which may exist in solution in the oil trapped within the host rock. An upper limit of the temperature to which the host rock is heated of 530° may apply, because thermal cracking of hydrocarbon vapours becomes very rapid at temperatures above 520 - 530°.

In some rock formations water may be present as chemically bound water in clays and other minerals. Permeability may also be increased during the heating process through the combined effects of thermal pressurisation and rock shrinkage that may occur through the thermally induced release of chemically bound water in clays and other minerals.

A laboratory test to demonstrate the method of the invention was performed using core samples from the tight oil Velkerri formation. A glass condenser tube containing the host rock sample was heated in a furnace to 500°C over a two hour period and then held at that temperature for a further two hours. This time period appeared to be sufficient for the removal of all fluids from the rock sample and for the condensing of the oil in the sample tube. It was noted, however, that oil began condensing on the side walls of the glass when the temperature of the system had only reached approximately 190°C. It is thought that most of the vaporised hydrocarbons are of the C_8 - C_{20} group of aliphatic hydrocarbons, of the type typically present in distillates. Indeed, the oil recovered from the host rock samples appear to be very similar to diesel oil.

The results of the laboratory tests on four samples of the host rock are summarised in Table 1 on page 7.

If sample 003H1 is adopted as a typical sample, the laboratory tests suggest:

host rock porosity 4.8%

oil as a percent of total fluids collected in condenser 10.6%

inferred gaseous phase loss 1.7 or 1.57%

Significantly, none of the host rock samples tested appeared to suffer any observable disintegration as a result of the heating.

In practice, in order to be economically viable, the host rock would probably need to be heated in-situ, although in principle the rock may be mined and transported to the surface for further processing using the method of the invention, for example, by heating in a suitable furnace. Mining of the host rock would have the additional benefit of

promoting fracturing to further enhance the permeability of the rock.

SAMPLE	002L1	003H1	004H2	005L2
INITIAL WT (g)	50	100.1361	101.1716	88.4096
FINAL WT (g)	not available	95.3414	96.2719	84.3428
WT. LOSS (%)	not available	4.8	4.8	4.6
TOTAL FLUID(g)	1.02	3.22	2.61	2.24
OIL LAYER (g)	no separate oil layer	0.34 (10.6%)	0.35 (13.4%)	0.15 (6.7%)
AQUEOUS LAYER (g)	0.67	1.96	1.38	1.46
OIL DISSOLVED IN AQUEOUS LAYER (g)	0.008 (0.75%)	0.04 (1.7%)	0.045 (1.7%)	0.039 (1.74%)
REMAINDER (g) (discarded water)	0.34	0.84	0.83	0.59
ALIPHATICS (%)				
Free Oil	-	52.8	67.5	52.9
Dissolved Oil	62.1	49.4	67.7	45.4
AROMATICS (%)				
Free Oil	-	32.4	23.0	29.8
Dissolved Oil	1.6	19.6	14.3	22.7
POLARS (%)				
Free Oil	-	14.8	9.5	17.2
Dissolved Oil	36.3	31.0	18.0	31.9

TABLE 1

According to a preferred method of the invention the host rock is heated in-situ by drilling one or more bore holes into the rock and supplying thermal energy to the bore hole. The thermal energy may be supplied by any suitable means, for example, by injecting heated inert gas into the bore hole from the surface. Alternatively, the thermal energy may be supplied by an electrical heater lowered into the bore hole. Figure 1 illustrates an experimental electrical heater 10 shown in-situ lowered in a bore hole 12 on a wire line 14.

The heater 10 comprises an electrical coil heating

element 16 of high electrical resistance through which a current is fed from the surface via electrical cable 18. Heat radiates radially from the heating element 16 into the adjacent rock formation 20 through a section of the wall of the borehole 12 approximately one metre in length. A radially decreasing temperature gradient will be formed in the rock formation 20 with a maximum temperature at the wall of the borehole 12. In order to ensure that most of the thermal energy radiates into the rock formation 20, spiral-shaped heat shields 22 are provided below and above the heating element 16, which reflect/deflect the thermal energy towards the wall of the borehole 12.

In order to inhibit combustion, heating is conducted in an inert atmosphere of nitrogen gas which is pumped into the space 23 surrounding the heating element 16 via gas line 24. The nitrogen gas is drawn back up to the surface through an aperture provided in the lower end 26 of the heater 10 which is connected to a suction line 28 that communicates with the surface equipment above ground (not illustrated). Nitrogen gas is also used to inflate a packer 30 provided at the upper end of the heater 10 above the heating element 16, for sealing the space 23 between the heating element 16 and the wall of the borehole 12. A cement plug 32 is provided below the heater 10 for sealing the space 23 at the lower end. The nitrogen gas provides positive pressurisation of the space 23 to act as a gas lift to the surface via line 28 of any fluids that collect in the bottom of space 23. The nitrogen gas also helps to cool the packer 30.

In use, heat generated by the electrical heater 10 propagates radially into the host rock, causing the temperature of the host rock adjacent the one metre section of the borehole wall to rise such that the temperature of the rock and hydrocarbons contained therein is slowly raised in a controlled manner in order to avoid pyrolysis. It is estimated that raising the temperature of the host rock to the desired level for a distance of one metre extending radially in all directions may take between 10 to 20 days, however this may vary considerably depending on the nature of the host rock.

As thermally induced pressurisation of the pores in the host rock containing the oil begins to occur, microfractures may begin to form increasing the permeability of the host rock. Some spalling at the wall of the borehole may also occur. Vaporised hydrocarbons and water vapour are liberated from the host rock 20 into the space surrounding the heating element 16, and from there are drawn to the surface via suction line 28 together with the nitrogen gas. At the surface the vaporised hydrocarbons and water are separated and collected for further processing. Any clays which may be present in the host rock will contain water which will also be vaporised causing the clay to shrink, which may further facilitate fracturing of the host rock.

The induced thermal pressurisation process may be employed in combination with other secondary recovery techniques. For example, prior to induced thermal pressurisation by heating, the host rock may first be subjected to artificial fracturing by means of hydraulic fracturing or by detonating an explosive charge within the host rock to increase permeability. A low shock energy explosive (LSEE) such as ANRUB described in copending Australian Patent Application No. 12477/92, would be suitable.

The induced thermal pressurisation process may also be combined with in-situ combustion to induce pyrolysis as either a pre- or post-processing step, or simultaneous with the induced thermal pressurisation. In-situ combustion cannot normally be employed in tight oil bearing rock due to the low permeability of the host rock. However, the permeability of the rock is increased during the induced thermal pressurisation process, which therefore facilitates the possibility of employing pyrolysis. Figures 3 to 5 illustrate several alternative methods for taking advantage of this synergy between the two techniques.

Each of the illustrated arrangements employs a different strategy for providing fuel for the enhanced hydrocarbon recovery process by either direct or indirect combustion of carbonaceous matter in the pay section of the host rock. In the drawings the following abbreviations are

employed:

BR1 = Barren overburden and any upper part of the pay section which has been processed and is barren.

PS = Pay section of host rock containing hydrocarbons. Some of this region may be barren due to prior processing.

BR2 = Barren rock under the pay section.

CC = Combustion chamber operates under controlled conditions to ensure the heated gas produced is at a controlled temperature and does not contain molecular oxygen. The latter condition is to prevent uncontrolled burning of product.

GD = Gas distributor designed to give spatially uniform heat and/or gas delivery to the section of the host rock being processed.

PL = Product line through which flue gas and hydrocarbons (gases, vapours and possibly liquids are withdrawn to the surface).

In the arrangement of Figure 2, at least one borehole 40 is drilled into the host rock, and sealing plugs 42, for example of cement, are inserted above and below the pay section (PS) of the host rock. The arrangement of Figure 2 is similar to that of Figure 1, except that the thermal energy is supplied by hot inert gases heated in a combustion chamber (CC) supplied with inert gas and a combustible fuel. In this arrangement some of the distillation product of the induced thermal pressurisation process is burnt as fuel in the combustion chamber. This fuel would comprise light hydrocarbons which cannot be sold economically due to geographical or other factors, as well as heavy hydrocarbons which suffer from the same disadvantages. A separation plant 43 separates the fuel from the saleable hydrocarbon product at the surface. If necessary, hydrocarbons from the saleable product could also be used as fuel to close the operational heat balance.

Figure 3 illustrates one possible method of combining in-situ combustion with one form of the method according to the invention. In this arrangement pyrolysis is employed as a

post-TORBIT processing step. Oil well 44 passes through a pay section of the host rock from which most of the tight oil has been recovered by induced thermal pressurisation at temperatures up to 530°C, typically between 300 to 500°C. In-situ combustion is now induced by burning the carbonaceous residue from distillation in a backfiring mode. Ignition in well 44 is initiated by commencing air flow into the well with the temperature at the well wall higher than the ignition temperature of the residue, or by using a supplementary fuel. The flow of hydrocarbons produced in PL1 will contain Pyrolysis tars/oils which may be of low value. These can be used as fuel in the combustion chamber for heating the inert gas injected into well 46 which operates according to the TORBIT process. PL2 carries the hydrocarbon product, water vapour and inert gasses from the TORBIT process in well 46.

The presence of molecular oxygen in PL1 would indicate either that the air flow rate in well 44 is excessive, or that backward firing of the in-situ combustion is no longer sustainable.

Figure 4 illustrates a similar arrangement to Figure 3, except that the carbonaceous residue from distillation is burnt in a forward firing mode. Carbonaceous residue is burnt in-situ in the previously distilled region of the pay section between wells 48 and 50. Well 48 has previously been operated under TORBIT conditions. Then well 50 is operated under TORBIT conditions until the distilled zones in the pay section between wells 48 and 50 interconnect. In-situ combustion may now be employed in this region due to the increased permeability of the host rock following TORBIT processing. Air heated above the ignition temperature of the residue, typically between 500 to 850°C, is injected into well 48 and drives a combustion front through the residue towards well 50, and the products of pyrolysis are drawn off from well 50 via PL1. The presence of molecular oxygen in PL1 would indicate that the fuel in the region between wells 48 and 50 is exhausted, or that gas channelling has occurred. Some of the products of pyrolysis recovered from well 50 are used as fuel for the combustion chamber in well 52 which operates a TORBIT process similar to

that of Figure 2.

The TORBIT process is maintained in well 52 until the distilled zones in the pay section of the host rock between wells 50 and 52 interconnect. This distilled region then becomes available for pyrolysis to produce a fuel source for further distillation in another adjacent well (not shown). This arrangement lends itself to a sequential operation in which the TORBIT process is performed in one well, followed by in-situ combustion to produce a fuel source for the TORBIT process in an adjacent well. When the TORBIT process is completed in the adjacent well, the adjacent well is employed for in-situ combustion to produce a fuel for the TORBIT process in a still further well, and so on. For simplicity, the illustrated arrangement shows the TORBIT process and/or in-situ combustion occurring with only one well at a time, however in practice more than one well can be operated simultaneously. Indeed, a network of both horizontal and vertical boreholes may be employed depending on the nature and distribution of the reservoir of tight oil and kerogens in the host rock.

In both the arrangements illustrated in Figures 3 and 4 the products of pyrolysis are separated from the products of the TORBIT process. However, in certain situations it may be possible to operate both processes simultaneously in the same well. Figure 5 illustrates such an arrangement in which a combustion front is driven through the previously distilled region between wells 54 and 56 in a forward firing mode similar to that illustrated in Figure 4. However, in this case the combustible products from pyrolysis in the previously distilled region between wells 54 and 56 are burnt in an external combustion chamber (not illustrated) for directly heating inert gas injected into well 56, to induce thermal pressurisation in the pay section of the host rock adjacent well 56. The products of both pyrolysis and the TORBIT process are drawn from well 56 through PL3 for separation at the surface.

As a variation on the same theme, an explosive charge may be detonated below ground, for example, in a horizontal drill hole to create a region of fractured host rock or a stope within which an in-situ retorting process can be performed.

Thermal energy generated in the subterranean retort heats the surrounding rock formation to induce thermal pressurisation which liberates the hydrocarbons from the host rock.

From the above description of various embodiments of the induced thermal pressurisation technique of the present invention, it will be evident that the invention may have application wherever conventional oil recovery techniques alone are not viable. It is thought that significant amounts of hydrocarbons are left in exhausted wells where conventional oil recovery techniques have been used. Heating of the host rock to induce thermal pressurisation may increase the mobility of any remaining hydrocarbons sufficiently to release them for recovery from the "exhausted" well. The induced thermal pressurisation may also cause fractures to be formed which increase the permeability of the rock formation surrounding the "exhausted" well, to further enhance the liberation of hydrocarbons therefrom.

Now that various arrangements for implementing the process according to the invention have been described in detail, it will be apparent to persons skilled in the relevant arts that numerous variations and modifications can be made, in addition to those already described, without departing from the basic inventive concepts. For example, other known methods of controlled heating subterranean rock formations, such as electromagnetic heating, may be employed to induce thermal pressurisation in the host rock. All such variations and modifications are to be considered within the scope of the present invention, the nature of which is to be determined from the foregoing description and the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of recovering hydrocarbons from host rock, the method comprising:

heating the host rock to induce pressurisation of hydrocarbons contained therein whereby the mobility of the hydrocarbons is increased sufficiently to allow the hydrocarbons to be released from the host rock.

2. A method of recovering hydrocarbons as defined in claim 1, wherein the host rock is subjected to controlled heating from an external heat source to temperatures at which vaporisation of the hydrocarbons occurs.

3. A method of recovering hydrocarbons as defined in claim 2, wherein the host rock is heated to a temperature within the range 150°C to 530°C.

4. A method of recovering hydrocarbons as defined in claim 3, wherein the host rock is heated in-situ and any hydrocarbons released are lifted to the surface via a borehole.

5. A method of recovering hydrocarbons as defined in claim 4, wherein the host rock is heated by injecting hot inert gas into a section of a borehole traversing the host rock.

6. A method of recovering hydrocarbons as defined in claim 3, wherein the host rock is first mined and then subjected to heating by external heating means.

7. A method of recovering hydrocarbons as defined in claim 1, combined with another secondary oil recovery method whereby, in use, recovery of oil from the host rock is enhanced by the combined methods.

8. A method of recovering hydrocarbons as defined in claim 7, wherein the other secondary oil recovery method

involves artificially fracturing the host rock whereby, in use, the permeability of the host rock is further increased.

9. A method of recovering hydrocarbons as defined in claim 7, wherein the other secondary oil recovery method involves in-situ combustion to induce pyrolysis of hydrocarbons in the host rock.

10. A method of recovering hydrocarbons as defined in claim 9, wherein fuel used for heating to induce pressurisation of oil contained in a region of host rock, is obtained by combustion of carbonaceous matter in another region of the host rock.

11. A method of recovering hydrocarbons as defined in claim 9, wherein a carbonaceous residue is ignited in-situ in a region of the host rock from which oil has previously been distilled by induced thermal pressurisation, and wherein a combustion front is driven through the residue towards a well from which the products of pyrolysis can be drawn off.

12. A method of a recovering hydrocarbons as defined in any one of the foregoing claims, wherein heating of the host rock to induce pressurisation of hydrocarbons contained therein also causes fractures to be formed which increase the permeability of the host rock.

13. A method of recovering hydrocarbons as defined in claim 12, wherein the oil in the host rock comprises tight oil.

14. An apparatus for recovering hydrocarbons from host rock, the apparatus comprising:

means for heating the host rock to induce pressurisation of hydrocarbons contained therein whereby the mobility of the hydrocarbons is increased sufficiently to allow the hydrocarbons to be released from the host rock.

15. An apparatus for recovering hydrocarbons as defined

in claim 14, wherein said means for heating comprises means for injecting a heated inert gas into a borehole traversing the host rock.

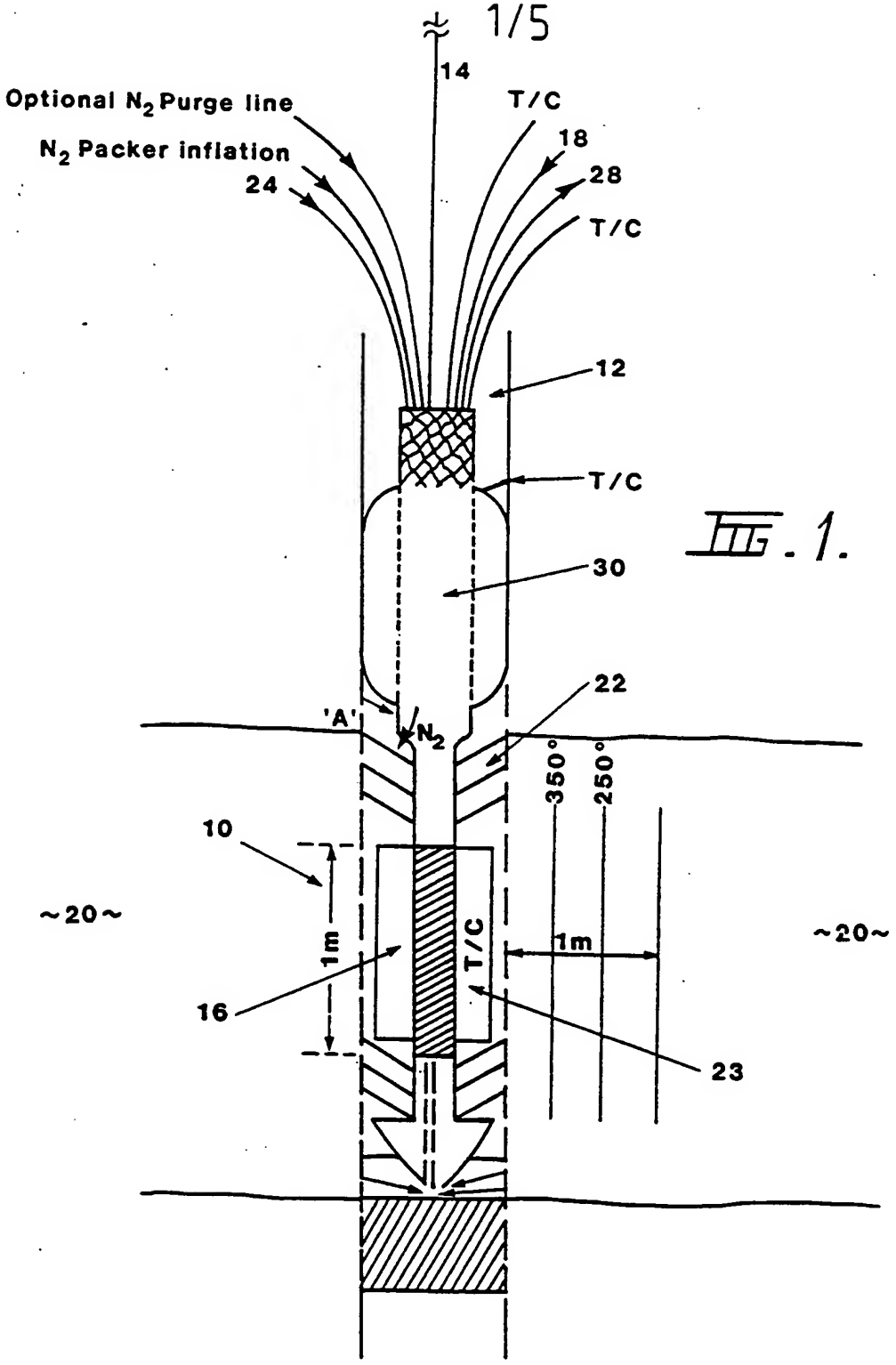
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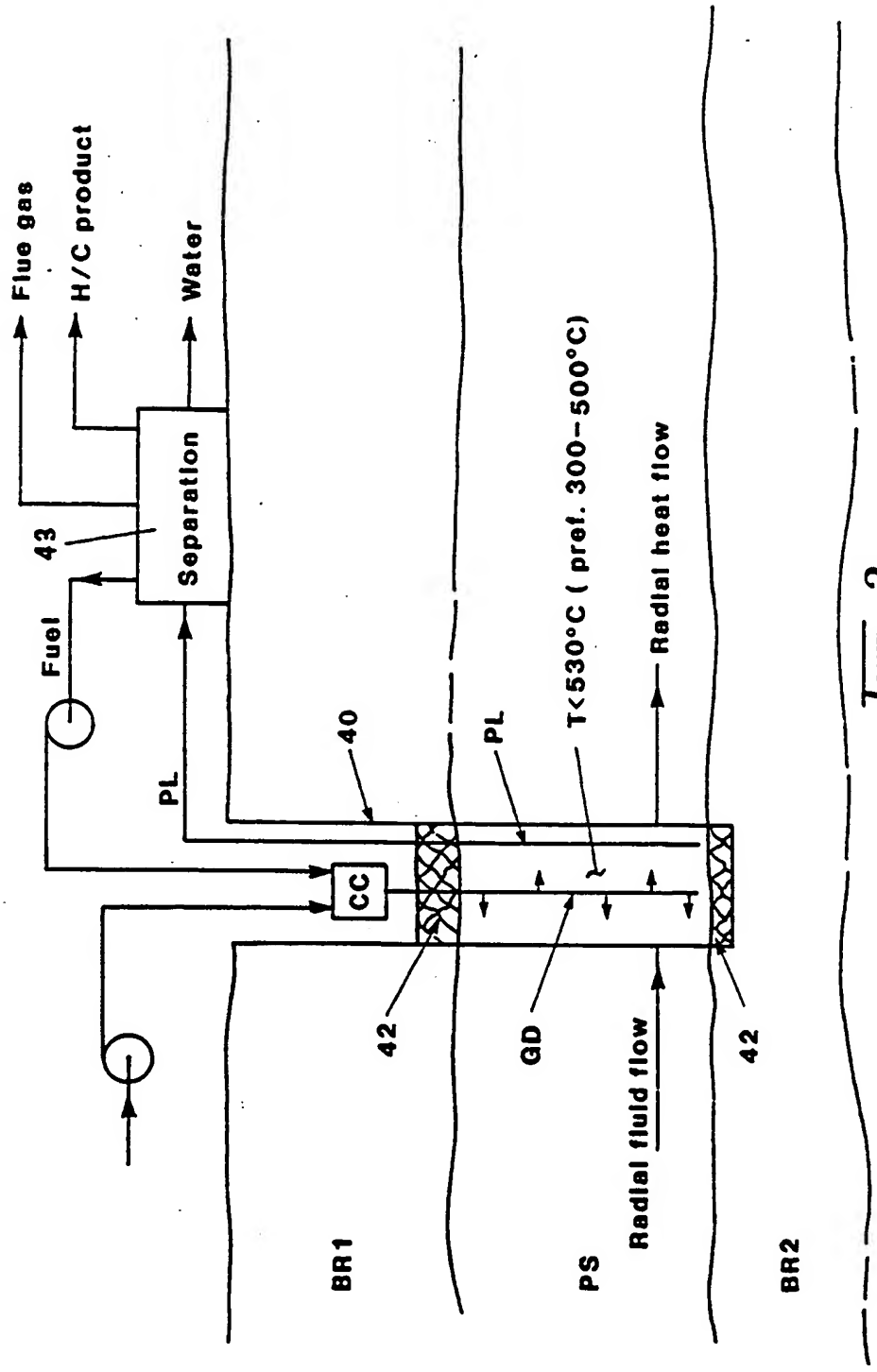
FIG. 1.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GD
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BR1
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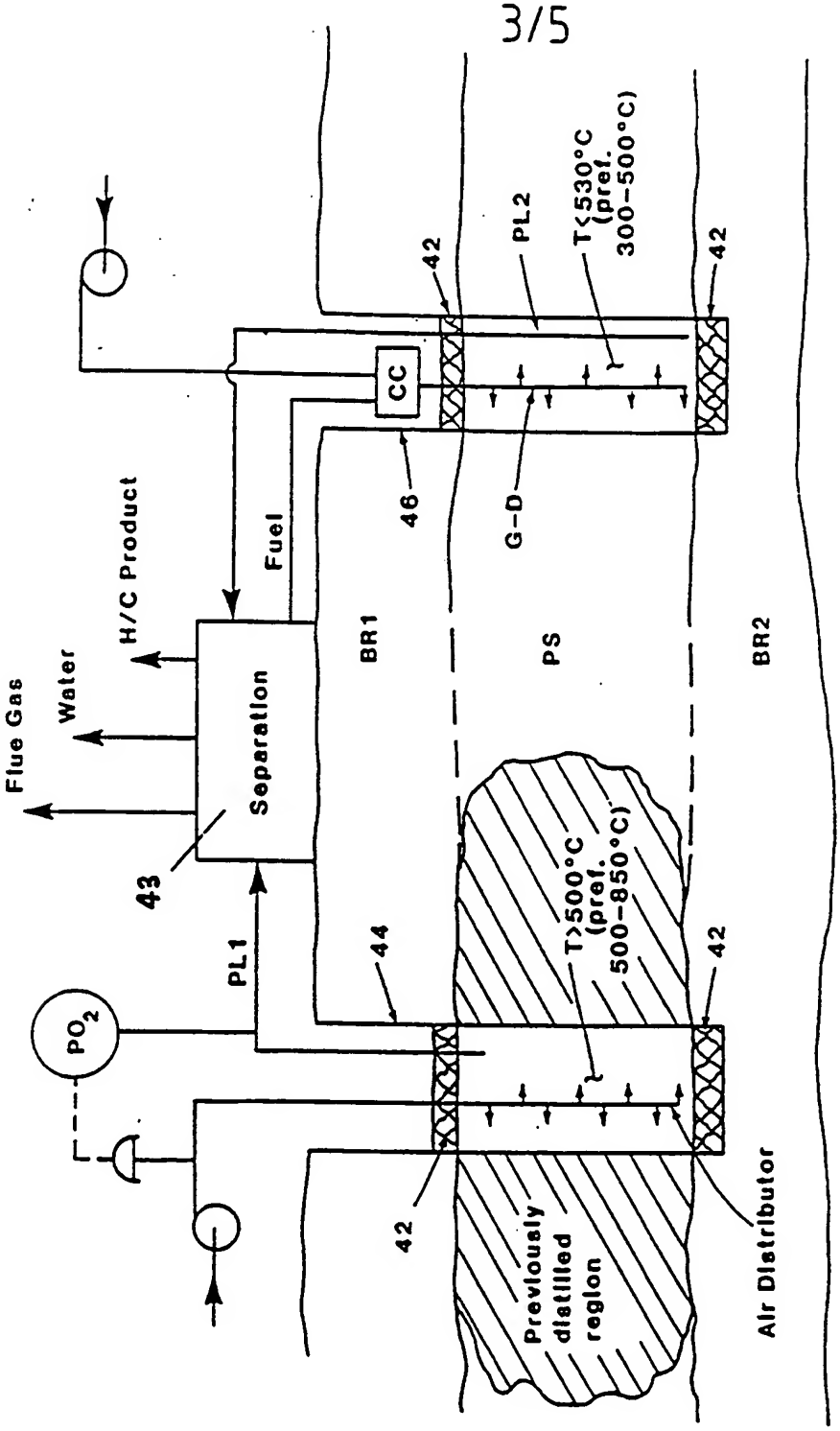
BR2

FIG. 2.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BR2
PL1
44
T>500°C
(pref.
500-850°C)
PO_2
Previously
distilled
region
Air Distributor

FIG. 3.

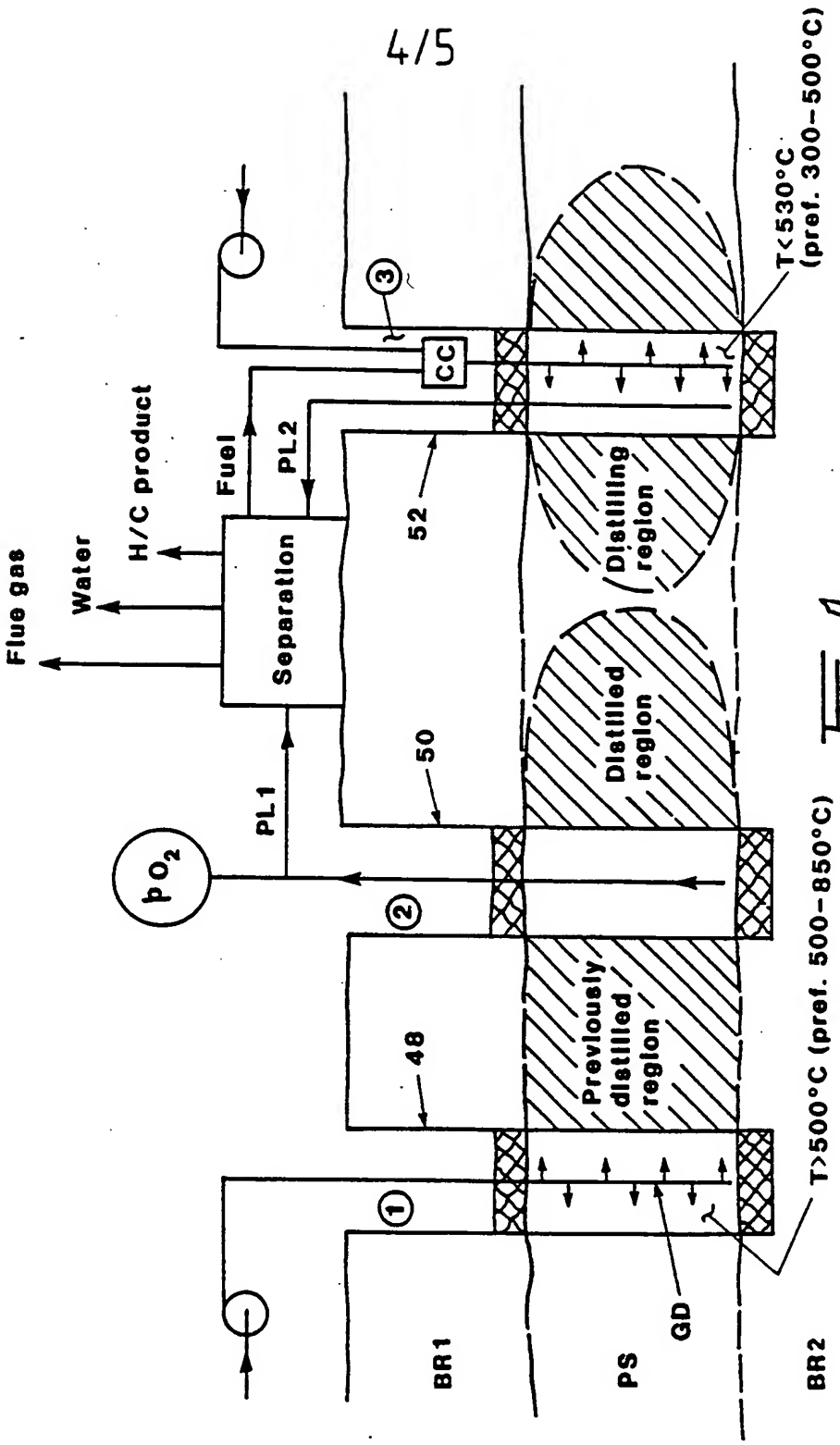
T<530°C
(pref. 300–500°C)
3
CC
Distilling region
52
PL2
Fuel
H/C product
Water
Flue gas
Separation
Distilled region
50
PL1
p_{O_2}
2
Previously distilled region
48
T>500°C (pref. 500–850°C)
1
BR1
PS
GD
BR2

FIG. 4.

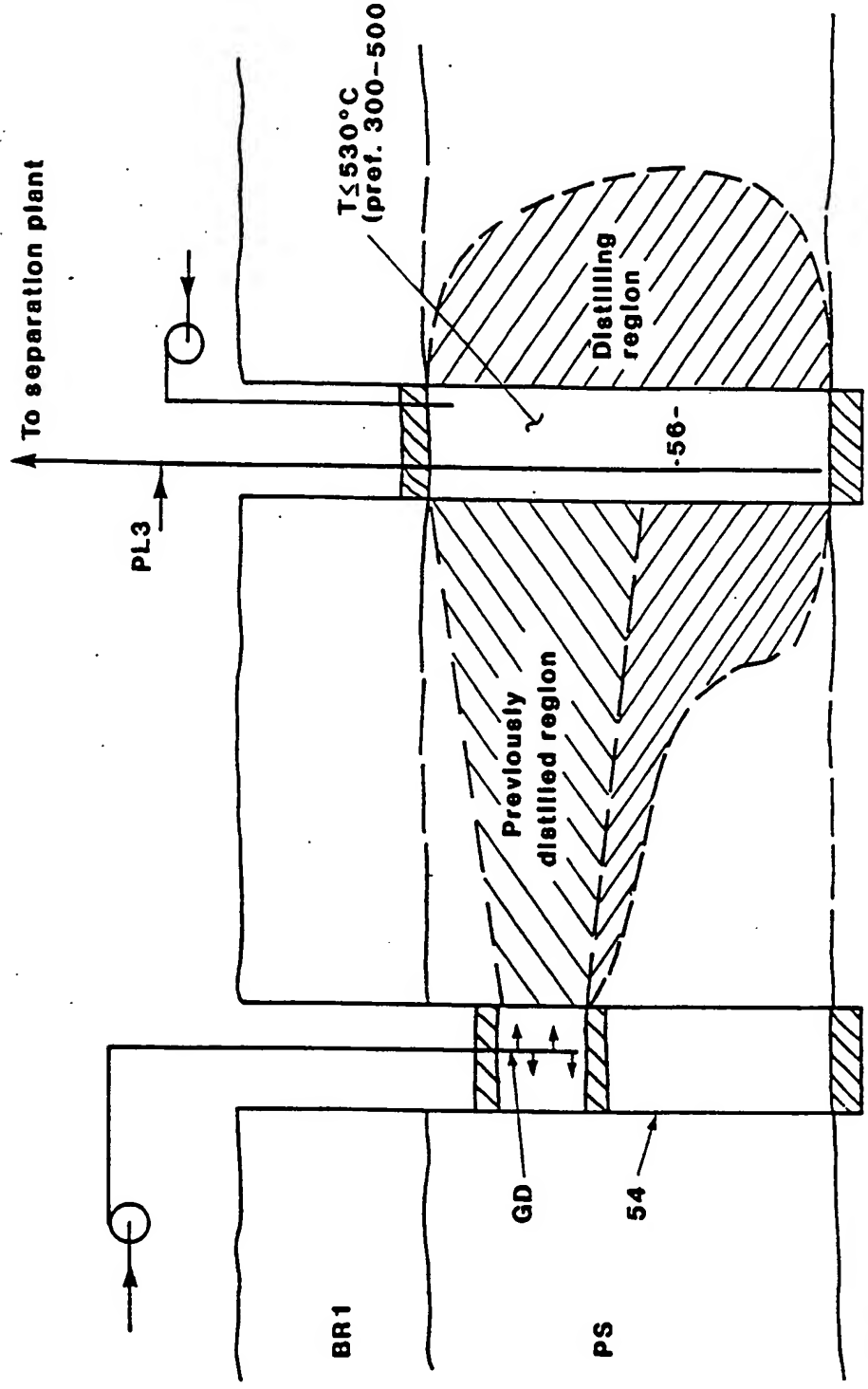
To separation plant
PL3
T≤530°C
(pref. 300-500°C)
Distilling
region
-56-
Previously
distilled region
GD
54
BR1
PS
BR2

Fig. 5.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 94/00488

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl.[6] C10G 1/02; E21B 43/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC C10G 1/02; C10B 53/06, 57/20; E21B 43/24, 43/243

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)
DERWENT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	US,A, 4473120 (JENNINGS) 25 September 1984 (25.09.84) See whole document.	1-8,12-15
X	AU,B, 20453/83 (563257)(IIT RESEARCH INSTITUTE) 3 May 1984 (03.05.84) See whole document.	1-6,14-15
X	US,A, 4304609 (MORRIS) 8 December 1981 (08.12.81) See column 4 lines 11-33.	1-3,6,14
X	AU,B, 82841/82 (543488) (SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.) 28 October 1982 (28.10.82) See page 1 lines 1-13 & page 3 lines 10-24.	1-3,6,14

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle of theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 November 1994 (14.11.94)	25 Nov 1994 (25.11.94)
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	Authorized officer B Bourke B. BOURKE Telephone No. (06) 2832148

Form PCT/ISA/210 (continuation of first sheet (2)) (July 1992) copjne

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
X	GB,A, 283639 (CROZIER) 9 February 1928 (09.02.28) See whole document.	1-3,6,14
X	AU,B, 1193/37 (103579) (ERNEST JOHN ROBIN COPP) 7 April 1938 (07.04.38) See whole document.	1-3,6,14

INTERNATIONAL SEARCH REPORT
Information on patent family member

International application No.
PCT/AU 94/00488

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
AU	20453/83	CA	1213547	US	4485869		
US	4304609	AU	67944/81	DE	3106293	DK	903/81
		FR	2478805	GB	2071138	NL	8100887
		SE	8100843	US	4304609	US	4453319
AU	82841/82	AT	1536/82	BE	892912	BR	8202281
		CA	1186260	DE	3214617	EG	15571
		FR	2504547	GB	2097017	LU	84097
		NZ	200353	SE	8202469	TR	22143
		US	4439306	YU	859/82	AT	1535/82
		AU	82842/82	BE	892913	BR	8202274
		CA	1189811	DE	3214616	EG	15722
		FR	2504548	GB	2097018	LU	84098
		NZ	200354	SE	8202468	SU	1366063
		TR	21195	US	4419215	ZA	8202675
		ZA	8202676				

END OF ANNEX